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APPLICATION FOR LETTERS PATENT

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TITLE:

BIOMIMICKING APPLICATIONS OF HUMAN SENSORY SYSTEMS

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BACKGROUND OF THE INVENTION

1.   Field of the Invention

Reference is made to Disclosure Document Number 518,460, Watkins. The invention relates to human sensory training and testing systems. More particularly, the invention relates to sensory training and testing systems focusing upon the development of pre-attentive and attentive vision for the enhancement of the individual's ability to perform specific functions.

2.   Description of the Prior Art

Imagine a situation where one of a person's senses, such as the vision from one eye, the hearing from an ear, the smell from a nose, the touch from one hand, has been impaired through damage to the nerves associated with such sense. What if the sense could be improved through use of the other unaffected senses. Imagine further a situation where one eye has better vision than the other. What if the eye with the better vision could be used to train the underperforming eye. The present invention relates to sensory training and testing systems focusing upon the development of the pre-attentive and attentive vision processes. To understand this method, one must first understand the concepts of pre-attentive and attentive vision.

Eagles have exceptionally good visual acuity being able to see a 10-cm long mouse body from a viewing height of hundreds of meters above the ground. This phenomenal vision is, however, constrained to a very small portion of their retina termed the fovea, which provides a detailed, but very limited, field of view. Humans have the same retinal configuration with a central fovea comprised of dense populations of three eye color cone sensors (red, green, and blue).

The eagle does not use its foveal vision to locate its prey though. The foveal vision has too small of a field of view and would be like looking at a large area picture through a soda straw. This task would be analogous to the "Where's Waldo" problem where there is just too much similar looking

1   clutter in the scene to easily locate the one correct object.

2   Eagles and other binaural predators locate their prey through the use of depth and motion cues

3   observed via the outer portion of retina, instead of trying to find a particular object in the large

4   background terrain area. Motion and depth cues are basically mathematically indistinguishable because

5   they represent a spatial shift of the object of interest against its background. For the case of the motion

6   cues, the spatial shifts are caused by movement of the object against its background in time. With regard

7   to the depth cues, the spatial shifts are a result of parallax between the lines of sight of the predator's

8   two eyes. While for the eagle the dominant cue for looking down on a more or less flat surface is

9   motion, for a lion looking out horizontally over the savanna for prey both motion and depth cues are

10   important (also, the lion may fuse the input cues from its senses in locating prey). Hence, both motion

11   and depth are considered important for predators.

12   The outer portion of the human retina, and other predators such as the eagle described above,

13   has a much sparser population density of cone sensors and thus can be used to analyze daylight visual

14   information more quickly using a process called pre-attentive vision. Once a depth or motion cue is

15   detected, the eagle moves its fovea onto this area and uses the maximum visual acuity portion of its

16   retina to identify whether the depth or motion cue was caused by an actual prey. This attentive vision

17   processing of the foveal vision though is slower than the pre-attentive vision.

18   Humans use two distinct types of vision processes. However, humans are not always aware

19   which one they are using at a particular time. The first type of processing is a whole scene interrogation

20   that is termed a "soft focus" in some sports. This is commonly considered to employ "pre-attentive

21   vision". The second type of processing is a highly fixated view of a portion of the scene in front of

22   them. This highly fixated processing is commonly call "attentive vision" and is used to read signs, for

23   example. What is not well known is that the pre-attentive vision process has a refresh rate that is five

1   times faster than the attentive vision process.

2   The typical human vision refresh rate (the time required to produce a single mental image from

3   the visual input of a person's foveal region, i.e., attentive vision process) is given as 200 milliseconds,

4   and the stereopsis and depth perception has a limit around 20 arcsec, which is representative of the

5   attentive vision processes. The pre-attentive temporal refresh rate, on the other hand, is typically given

6   as between 25 and 32 Hz or approximately 40 milliseconds, which is five times faster than the attentive

7   vision process.   Processing speed is a very important aspect in the search and target

8   acquisition/recognition process. To perform this task efficiently, humans must rely upon the pre-

9   attentive vision process and not attentive vision.

10   The human vision processes have developed very sophisticated calibration techniques that occur

11   without an awareness of their existence or implementation. That does not, however, mean that humans

12   always have perfect vision and use the correct vision processes to address every vision problem

13   encountered.   Humans sometimes use intuition to solve vision problems and actually apply very

14   inefficient methods for their solutions. There have been some attempts in the past to train pre-attentive

15   vision without the knowledge of why the process works. Reading in general is performed as an attentive

16   vision process where the foveal field of view at the typical reading distance of 60 cm has a width of

17   approximately 2 cm. This allows even long words to be completed foveated (placed within the foveal

18   field of view for identification). But humans are very familiar with the spelling of words and only

19   recognition is needed to understand that a string of letters represents a particular word. In fact, humans

20   can recognize strings of words without really identifying the individual words. This is the process that

21   speed reading uses to increase the rate at which humans can derive the meaning from written text. What

22   is not recognized by the users of this approach is that they are using pre-attentive vision that performs

23   recognition vision processes five times faster than the foveal attentive vision identification process.

1   Based upon the foregoing understanding relating to pre-attentive vision, it is desirable to

2   develop a vision training techniques which improve upon one's ability to utilize pre-attentive vision in

3   an effective manner. The notion, however, that human senses including vision can be trained or

4   enhanced in not novel. For example, U.S. Patent Number 4,405,920, for Enhancing the Perceptibility

5   of Barely Perceptible Images, Naomi Weisstein, Inventor, issued in 1983, discusses the use of a

6   computer program to enhance visionary perception of faint images. Additionally, U.S. Patent Number

7   5,088,810, for Vision Training Method and Apparatus, Stephen Galanter and Barry Millis, inventors,

8   issued in 1992, involves different types of computer generated therapeutic eye exercise routines to

9   increase performance. U.S. Patent Number 6,364,486, for Method and Apparatus for Training Visual

10   Attention Capabilities of a Subject, Karlene K. Ball and Kristina K. Berg, inventors, issues in 2002,

11   discloses the use of a computer algorithm to improve attention vision.

12   Attempts at visual training have been specifically applied in treating dyslexia. Dyslexia is a

13   problem that is related to how the human eyes' imagery is processed. As recent as September 2002, U.S.

14   Patent Number 6,364,486, for Method and Apparatus for Treating Dyslexia, was issued to Alison Marie

15   Lawson. The Lawson Patent is based upon the theory that Dyslexia is the result of unstable focus in

16   one eye. According to Lawson, Dyslexics do not appear to fully use their magnocellular pathways,

17   which are the pathways used in the brain to process fast moving objects. Dyslexia, according to

18   Lawson, can be improved by strengthening of the magnocellular visual pathways through repetition of

19   eye exercises. Lawson, however, fails to understand the true root to the Dyslexics problem and

20   therefore discloses an inefficient remedy to such problem. Dyslexia is a problem associated with the

21   way in which the left or right ordering of numbers or letters is perceived using attentive vision. Pre-

22   attentive vision in a Dyslexic is not affected. Unlike the method disclosed in the Lawson Patent, the

23   present invention describes a method of training Dyslexics using pre-attentive vision to calibrate or

1   correct the problems associated with attentive vision.

2   Vision training has also been used in relation to sports, specifically baseball players. In an article

3   published in the 2002 edition of the magazine entitled "Coaching Management", David Hill the author,

4   speaks of training baseball players to be better hitters through vision exercises. Mr. Hill relates on page

5   18 of his article, how important it is to a baseball player to be able to see the ball before it is hit.

6   Notwithstanding the opinions of Mr. Hill, however, and as stated on page 171 of the book entitled

7   "Keep Your Eye on the Ball", Robert G. Watts, A. Terry Bahill, W.H. Freeman and Company, 2000.

8   tracking a baseball moving at 100 mph, would require head and eye rotations in excess of 1000 degrees

9   per second; an impossibility. Looking at an object (i.e., keeping your eyes on the ball) is an identification

10   process using attentive vision, and the batter already knows that he is supposed to hit a baseball. The

11   actual task that is needed is to track the path of the baseball in order to be able to swing the bat at the

12   right time and place to be able to solidly contact the ball. This is a search and target acquisition task and

13   not an identification task (requiring attentive vision). So the batter really should not look at the baseball

14   but, rather, the background instead. The batter must use pre-attentive vision instead of attentive vision

15   that simply is not fast enough to be used to follow the fast moving object. The veracity of this

16   observation is easy to justify by way of example. Jugglers who must simultaneously track several objects

17   cannot possibly track all of the objects that are being juggled by looking at them. They look at the

18   background past the objects and are thus able to use the fast response pre-attentive vision to track them

19   all at the same time.

20   While the concept of sensory training may not be novel, none of the prior art mentioned above,

21   recognizes the value of using pre-attentive sensory perceptions to enhance attentive vision. With this

22   in mind, the proper vision or sensory process or sequence of processes must be applied if one wishes

23   to optimize the performance of a task. Furthermore, it is known that human vision can be efficiently

1   trained if it is routinely exposed to the proper visual input for performing the process required for a

2   particular task. In fact, some vision defects can also be cured or mitigated by altering the visual input to

3   the eyes or training the eyes with the proper visual input images. Use of other senses such as hearing,

4   smell and touch can be uses to strengthen the foregoing. The present invention overcomes the

5   shortcomings of the techniques discussed above and provides an effective and efficient vision and

6   sensory training and testing technique.

7   SUMMARY OF THE INVENTION

8   It is, therefore, an object of the present invention to provide an efficient sensory training method.

9   Other objects and advantages of the present invention will become apparent from the following detailed

10   description when viewed in conjunction with the accompanying drawings, which set forth certain

11   embodiments of the invention.

12   BRIEF DESCRIPTION OF THE DRAWINGS

13   Figure 1 is a schematic of a display used in accordance with a preferred embodiment of the

14   present invention.

15   Figure 2 is a display used in treating dyslexia in accordance with the present invention.

16   DESCRIPTION OF THE PREFERRED EMBODIMENTS

17   The detailed embodiments of the present invention are disclosed herein. It should be

18   understood, however, that the disclosed embodiments are merely exemplary of the invention, which may

19   be embodied in various forms. Therefore, the details disclosed herein are not to be interpreted as

20   limiting, but merely as the basis for the claims and as a basis for teaching one skilled in the art how to

21   make and/or use the invention.

22   With reference to Figure 1, a vision training system is disclosed which employs the use pre-

23   attentive vision in enhancing the mental processes of subjects. In accordance with a preferred

1   embodiment of the present invention, the process involves first creating a three-dimensional

2.   environment including at least two objects of shape, including a first object and a second object, situated

3   in front of a background. The first object and the second object are spaced beyond the horizontal

4   angular extent an individual is able to foveat using attentive vision. That is, the objects are spaced in a

5   manner preventing an individual from using attentive vision to observe both objects simultaneously. The

6   first object and the second object are further positioned to produce either motion cues, color cues

7   and/or depth cues. Thereafter, the three dimensional environment is viewed by an individual and the

8   response of an individual is studied to ascertain their ability to utilize pre-attentive viewing.

9   In accordance with a preferred embodiment of the present invention, the three dimensional

10   environment is simulated on a two-dimensional display monitor. In addition, the horizontal angular

11   extent required to prevent the use of attentive vision is 2 degrees of the entire width field viewed by the

12   individual and the first object and the second object are positioned to produce depth cues by varying the

13   depth range difference between the first object and the second object. In addition to the use of depth

14   cues and motion cues, the textural contrast between the background and the first and second objects is

15   varied to optimize the use of pre-attentive vision and/or enhance the testing process. Textural contrast

16   is altered by varying color composition, edge fidelity, noise and intensity.

17   As discussed above, human vision is often characterized only for the attentive vision process.

18   The temporal refresh for attentive vision as mentioned above is generally regarded to be approximately

19   200 msec, and the stereopsis and depth perception has a limit around 20 arsec. In contrast, and as

20   discussed above, the pre-attentive temporal refresh rate is generally considered to be approximately 40

21   msec, which is five times faster than the attentive vision. The pre-attentive depth perception limit is

22   approximately 3 arcmin at a nominal 10-degree separation, which is less sensitive than the attentive vision

23   as measured for the central foveal vision.

1   The visual input for measuring and training human pre-attentive vision in accordance with a

2   preferred embodiment of the present invention will now be detailed. Both depth and motion cues are

3   determined through the fusion of the backgrounds viewed by both the left and right eyes. This is

4   sometimes referred to as "stereoscopic fusion". This stereoscopic fusion is accomplished nearly

5   instantaneously by our two eyes based on coarse spatial structure and shading features that represent

6   more or less a vertical surface at a distance as seen from two lines of sight with horizontal angular

7   separation (that is, left and right eyes which are horizontally separated).

8   In accordance with a preferred embodiment of the present invention, two objects of shape

9   relating to the task of interest are used. Spheres, for example, can be used for baseball players. The two

10   objects of shape are placed in the 3-dimensional (3-D) scene representation using a computer aided

11   design (CAD) program such that they are approximately 2/3 of the distance to the background and are

12   positioned with horizontal separation.

13   With reference to Figure 1, and in accordance with a preferred embodiment of the present

14   invention, a typical display would be a 43-cm monitor having approximately a 33-cm width that

15   represents a 20-degree width field of view when the monitor is viewed from a distance to of 90 cm. A

16   human can foveate approximately 10 percent of the horizontal angular extent of such a display or 2

17   degrees of the entire width field viewed by the subject. In order to force the observer to use pre-attentive

18   vision rather than attentive vision, the spheres' closest edges must be separated by more than the 2-

19   degree foveal extent (that is, 3.2 cm at 90-cm viewing distance).

20   In accordance with a preferred embodiment of the present invention, a typical scene would

21   contain two 5-cm diameter spheres positioned with their centers located 9 cm from each side of the

22   display. This produces a 10-cm separation between the inside edges of the two spheres. The diameter

23   of the sphere is such that it is larger than the angular extent of the foveal vision and allows the spheres

1   to be textured with coarse, medium, and fine spatial structure as used with attentive vision processes.

2   Spatial structure can be explained by example. In a scene of a dining room, the large objects like the

3   table, chairs and people would represent low frequencies. The plates on the table and the people's heads

4   and limbs would represent medium frequency objects. The utensils, the people's fingers and designs on

5   the plates would represent the high frequency or fine detail objects.

6   The 6.5-cm separation between the outer edges of the spheres and the outer edges of the

7   respective right and left background edges of the display, prevent attentive vision from relating the edge

8   of the background to the sphere's location in the background. In general, the size of the spheres and the

9   spacing of the spheres substantially prevent the use of attentive vision for performing the depth

10   determination task.

11   When employing the configuration described above, the background for the 3-D volume space

12   (as defined and simulated within the two dimensional space of the display) could be situated as an xy-

13   plane at a range of 1500 units in the z-direction from where the viewing takes place. If x represents the

14   horizontal dimension, then the viewing locations for forming the stereo pair images will be plus and

15   minus 7.5 units from z =0. This gives 10-mrad angular separation for the 1500-unit range for the

16   background. The two spheres are positioned around a range of z = 1000 with x positions of plus and

17   minus 83.33 units that corresponds to an angular separation of 9.46- degrees between the centers of the

18   spheres or a projected separation of 250 units at the background range of z = 1500 units. For

19   measurement purposes, the spheres are positioned at 25-unit intervals closer and farther than the 1000

20   nominal z-axis value. If the left sphere is positioned farther away (say 1025) then the right sphere is

21   positioned closer (correspondingly at 975). The size of the spheres must also be changed with their range

22   positioning to maintain their relative size of 83.33 unit diameters at a z-axis range of 1000 units. The

23   sphere at 1025 z-axis range would have a diameter of 85.42 units, and the sphere at 975 range would have

1   a diameter of 81.30. All of these spheres have the same projected diameter of 125 units at the 1500-unit

2   background range.

3   At this point it is instructive to gain a perspective of how sensitive human depth perception

4   resolution is compared to that of the 43-cm monitor with 1024 x 768 pixel resolution. At a viewing

5   distance of 90 cm each pixel has approximately a 70-arcsec width. For the attentive vision stereopsis

6   limit of 20 arcsec, this would imply that a shift of only 2/7 of a pixel is needed to be able to see the depth

7   difference between two surfaces at a viewing range of 90-cm or a one pixel offset for a viewing range of

8   3.15 m.

9   The pre-attentive vision depth perception limit for objects separated by a few foveal regions is

10   about an order of magnitude less sensitive that the attentive vision because there are about 60,000 cones

11   in the foveal region out of about 6.5 million in the entire retina. There are about 100 times as many

12   cones outside the foveal region covering an area nearly 10,000 times larger than the foveal region. Hence,

13   the cone density is an order of magnitude less in each direction. As a result, the required display spatial

14   resolution is less when training and/or testing pre-attentive vision as compared with attentive vision.

15   This allows for a viewing range of 90 cm provided that CAD modeled images used are at least 512 X 512

16   pixel resolution. In accordance with a preferred embodiment of the present invention, the 512 X 512

17   resolution image can be used for fast Fourier transform (FFT) analysis of the image spatial frequency

18   content but would have to be cropped (1/8 off the top and 1/8 off the bottom) to 512 X 384 before

19   being imported into a PowerPoint display and expanded to the 1024 X 768 pixel monitor display.

20   In terms of the requirements of measuring the 3-arcmin pre-attentive depth perception limit for

21   the 10-degree object separation at a viewing range of 90 cm, an offset of the objects' centers of 2 to 3

22   pixels at the 1024 X 768 pixel display or 1 to 2 elements at the 512 X 384 model resolution is needed.

23   The positioning requirements that this imposes for the CAD 3-D scene model generator for use

1   in training and testing in accordance with the present invention are shown in Figure 1. This is a y-axis,

2   or top down view, of the objects, background, and camera positions in the xz-plane. The scale in the

3   two axial directions as shown in Figure 1 are different to permit viewing of the small detail of the

4   extrapolated sphere centers in the background xy-plane. The x-axis scale is ratio is 3:10. It should be

5   noted that the two spheres are shown as circles even though the z-axis projections are not to scale. The

6   left [1] and right [2] camera positions (representing the human subject's left and right eye viewing

7   locations) are equally spaced around the central scene origin [3] at (0,0). The separation between the left

8   camera [1] position (-7.5, 0) and the right camera [2] position (+7.5,0) is 15 units in the x-axis direction.

9   The two spheres of diameter 83.33 units have their centers positioned at a z-range of 1000 units. The

10   left sphere center [4] is located at (-83.33, 1000). The right sphere center [5] is located at (+83.33, 1000).

11   The projection of the left sphere onto the background plane at a range of z = 1500 [6] is positioned at

12   (-125, 1500); the right sphere center projection [7] is positioned at (+125, 1500). The two sphere centers

13   thus have again a separation of 250 units that at a range of 1500 units represents an angular separation

14   of 9.46 degrees. For the left camera, the left sphere center projection in the background plane [8] is

15   positioned at (-121.25, 1500) while the right sphere center projection [9] is positioned at (+128.75, 1500).

16   The two spheres have again a separation of 250 units at the background range. For the right camera, the

17   left sphere center projection in the background plane [10] is positioned at (-128.75, 1500) while the right

18   sphere center projection [11] is positioned at (+121.25, 1500). Yet again the two spheres have a

19   separation of 250 units at the background range.

20   Human pre-attentive depth perception will not be able to discern any difference in the range of

21   the two spheres because the parallax is the same magnitude for both. If the left sphere center is moved

22   50 units further away to the position [12] located at (-83.33, 1050) and the right sphere center is moved

23   50 units closer to the position [13] located at (+83.33, 950), then there is a 100-unit difference in depth

1   between them. The left camera now has a new left sphere center projection [14] of (-115.83, 1500)

2   against the background and a new right sphere center projection [15] of (+135.92, 1500), or a separation

3   distance of 251.75 units. The right camera now has a new left sphere center projection [16] of (-122.26,

4   1500) against the background and a new right sphere center projection [17] of (+127.24, 1500), or a

5   separation distance of 249.50 units. There is thus a 2.25-unit difference in the parallax separations

6   between the sphere centers against the background. The 20-degree field of view of the scene has an x-

7   axis extent [18] of 364 units at the 1000-unit range in the z-direction and an x-axis extent [19] of 546 units

8   at the 1500-unit range in the z-direction. Hence, the parallax difference of the spheres against the

9   background is 2.25 units or 5.2 arcmin, which is just larger than the 3 arcmin pre-attentive vision depth

10   perception limit. Hence, sphere center positions of z-axis ranges of 900, 925, 950, 975, 1025, 1050, 1075,

11   and 1100 are used to produce range differences between the left and right sphere centers of 50, 100, 150,

12   and 200 units. The 50-unit difference case has a parallax difference of 2.6 arcmin, which is less than 3-

13   arcmin limit. As such, by varying the range differences one is able to train individuals to effectively use

14   pre-attentive vision. To avoid problems of pixel value extrapolation, the background could be moved

15   to a range of 1406.7 units where the x-axis extent would be exactly 512 units, or the angular extent could

16   be reduced to 512 units at the 1500 z-axis range, which would represent and 18.85-degree width.

17   If more precise measurement of the pre-attentive vision depth perception is needed, the CAD

18   3-D model could be used to produce 1024 X 1024 pixel images that can be cropped to 1024 X 768 pixel

19   images for display. Even with this though, it is not possible to obtain sufficient precision in the

20   measurement of the pre-attentive vision depth perception limit by simply finer resolution adjustments

21   of the sphere centers z-axis separation because of the pixel value extrapolation errors that occur. The

22   measurement precision must, therefore, be derived by varying the parameters that impact the human

23   vision derivation of the pre-attentive vision depth.

1   The actual measurement of the pre-attentive vision depth perception limit is dependent upon the

2   difference of the texture contrast between the sphere and the background. This contrast difference for

3   daytime vision is determined using the eyes' cone sensors since the rod sensors are used for low light

4   level vision. Parameters that influence this contrast include: textural spatial frequency, color composition,

5   edge fidelity, noise, and intensity. The intent in accordance with a preferred embodiment of the present

6   invention is to use a set of these parameters that can be varied to produce a range of contrast differences

7   that will vary the measured value of the preattentive depth perception for the scenes generated with a

8   fixed set of separation ranges between the two objects used to obtain more or less a continuum of

9   difficulties for the range separations chosen.

10   Of the variables, the one with the least control between subjects is the intensity. Hence, the

11   intensity is simply set to be bright enough to see the images comfortably. The next problem area arises

12   with respect to edge fidelity and noise. Sphere edges with essentially step function transitions are least

13   susceptible to the effects of noise. As will be seen below to be effective for color contrast variation there

14   must be significant levels of noise randomly applied to single color scene layers to produce colored

15   backgrounds. This results because the CAD 3-D model produces grayscale and not color images.

16   Hence, the edges of all of the textures used will be high contrast with sharp edge transitions. The

17   parameters that will be used to produce variability in the pre-attentive depth perception measurement

18   and training are textural spatial frequency, color composition, and noise.

19   The textural spatial frequency will be discussed first. The texture of the background must be

20   selected. A sharp edged pitted structure is a reasonable choice since there are a lot of multi-edged

21   surfaces that can be made shiny. If several illumination sources are used in the simulation, many

22   multifaceted light and dark patches are produced. The coarseness of the texture must be selected to

23   provide a reasonable number of 4 – 6 cycle frequency patches over the 512 X 512 model spatial

1   resolution. This low frequency content is needed in the background so that it will not be completely

2   destroyed even by the largest levels of noise used.

3   The texturing of the sphere surfaces will now be discussed. The spheres have a projected

4   diameter extent of 125 units at the background z-range. Three levels of spatial frequency content are

5   chosen - low, medium, and high. For the 125-unit extent these could be represented by 1.5 – 3 cycles

6   (low), 7 – 12 cycles (medium), and 20 – 50 cycles (high). In terms of the whole scene extent these would

7   be 6 – 12 cycles (low), 30 – 50 cycles (medium), and 80 – 200 cycles (high). The actual textures could be

8   periodic like a checkered pattern but should not be oriented vertically and horizontally. In addition, both

9   spheres should not have the same orientation. Also, two periodic patterns should not be selected that

10 produce pronounced beat frequencies. Hence, random structured textures are preferred, but care must

11 be taken that in forming mid-range overall intensity the spatial frequency range is maintained.

12   One final note should be stressed in terms of the placement of illumination sources used in the

13 simulation. The spheres must not cast recognizable characteristic elliptical shadows on the background.

14   The next parameter to be discussed is the use of color. The simplest choice is the primary colors

15 (red, green, and blue) that correspond to the peaks of the human eye's cone sensors. Most CAD 3-D

16 models produce grayscale texture patterns instead of multi-color texture patterns on the spheres. In

17 accordance with a preferred embodiment, only one of the three texture patterns is used at a time and only

18 one of the primary colors is used. The other two colors can be separately used on the remaining two

19 patterns. In accordance with a further embodiment, a composite image can be formed by merging all

20 three colored texture patterns to produce a multi-colored pair of spheres. The background, however,

21 would remain as a grayscale because it is composed of equal amounts of the primary colors on the same

22 texture pattern.

1   The issue of the grayscale representation of the background is not really a problem when the

2   noise is added. As mentioned before, it takes a large noise level to destroy the edge content of step

3   function edges. To produce multi-colored noise, random Gaussian noise is added to the separate texture

4   pattern sphere images before they are colored. The images are digitized to 256-bit grayscale resolution.

5   The individual images are contrast enhanced to produce many edges with the maximum grayscale

6   difference. In order to destroy the edges of the images the noise must have a standard deviation that is

7   on the order of, or larger than, this grayscale contrast difference. Three noise levels are thus chosen to

8   accomplish this to varying degrees. The standard deviations for the Gaussian noise are 240, 360, and 480.

9   Under the strongest noise, only a few percent of the background edge pixels are unaltered, yet the low

10   frequency structure is still preserved because in stereo viewing only correlated components are retained

11   and uncorrelated noise is discarded in the final representation of the scene content.

12   The final issue to be dealt with in the construction of the measurement and test images for pre-

13   attentive depth perception is the background positioning. The background must be presented with

14   several variations so that characteristic features or edges cannot be used with attentive vision to determine

15   the depth of the individual spheres, especially when the test is given repeated for training purposes. A

16   typical set of measuring or training images would be a random ordering of scenes of permutations of the

17   variable parameters. There are eight different range scenes, six different color-texture patterns, and three

18   different noise levels. Thus there would be 144 different scenes in the test. These images should be

19   viewed at a fairly rapid pace to reduce the tendency of the observer to use attentive vision since the pre-

20   attentive depth perception is determined very quickly once the stereo images are fused. Several different

21   orderings of these 144 scenes can be produced for non-repetitive training purposes. There are many

22   applications for this pre-attentive vision measurement and training including: any sport where a fast

1   moving object is tracked, navigation of vehicles or aircraft, improved speed reading, and post operative

2   training for lasik surgery patients.

3   If used to improve a baseball player's pre-attentive depth perception, the addition of an audio

4   signal could enhance the player's application of their pre-attentive skill relating to hitting. An object

5   tracker could be used to track the path of a pitched ball. A sound could be produced that represents the

6   range of the ball to the batter's strike zone over home plate. As the ball approaches close to the strike

7   zone, the pitch and/or volume level of sound could be increased until the ball finally reaches the strike

8   zone at which time a definite noise could be made to represent that the pitch was a strike and should be

9   contacted by the batter with his/her swing. If the pitch was not in the strike zone, no special sound

10   would be made. Repeated training would allow the batter to use his hearing to hone the visual tracking

11   skills needed to improve his batting percentage.

12   As discussed in the Background of the Invention, it is believed that measurement and training

13   in accordance with the present invention can also be applied to some attentive vision problems, such as,

14   dyslexia. The present invention applies pre-attentive vision training and testing in helping people

15   overcome the problems associated with dyslexia. Reading, and in particular visual training to overcome

16   dyslexia, is performed in an environment where the printed words or numbers are typically grayscale

17   images that have no depth or color variations present for calibration. The key to proper training for the

18   patient with dyslexia is to present letters and/or numbers in a display where pre-attentive vision is used

19   to determine the ordering.

20   More particularly, and in accordance with a preferred embodiment of the present invention,

21   Windows' Paint, a computer application providing for desktop publishing, can used to produce a grid

22   of random letters. By way of example, if 12-point bold capital letters are used with basically five spaces

23   (letters like "W" require less and "I" requires more) between letter and two-line spacing, a 20 wide by 12

1   high array can be produced. This can be displayed using PowerPoint similar to the scheme used for the

2   training and testing of pre-attentive vision described above but such that the width represents a 10-degree

3   extent. Under these conditions there will be four or five consecutive letters in a line within the foveal

4   region. The letter grid pattern can have letters removed to produce word size groupings or left as a

5   complete rectangular grid. This array can be presented to both eyes either with black letters on a white

6   background or white letters on a black background to determine the subject's degree of dyslexia in

7   identifying the order of the letters by reading the first line left to right and the second line right to left,

8   etc.

9   This test can also be performed using primary color lettering where the entire grid letters are

10 either red, green, or blue against either white or black background. To calibrate out the problem of

11 dyslexia requires that the left and right grid letters have a color-depth ordering in the pre-attentive vision.

12 This is accomplished by producing a grid with letters in a pattern that have been offset to produce

13 different depths that have different colors assigned to them. For example, if the evenly spaced set of grid

14 letters is viewed by the right eye in a cross eyed stereo pair, the spacing of the left eye letters in the grid

15 can be changed to produce peaks and troughs. The peaks are produced by shifting the letters one space

16 to the right. For any particular letter this is accomplished by moving one of the spaces on the right side

17 of the letter to the left side of the letter. This changes just that one letter with respect to the rest of the

18 grid. It appears closer than the other letters. This process can be applied to the first letter and every

19 third letter after it on the first line, the second letter of the second line and every third letter after it on

20 the second line, the third letter of the third line and every third letter after it on the third line, and the first

21 letter of the fourth line..., etc. This produces diagonal peaks in the letter grid that move from left to

22 right down the grid.

1   The middle depth region of the grid is produced by leaving the letters directly right of the peak

2   letters or two letters to the left of the peak letters alone. The troughs are produced by shifting the

3   remaining letters one space to the left using the same process that was applied to the peak letters to shift

4   them one space to the right. This produces a letter grid that has both peaks and troughs that proceed

5   diagonally from the left to the right down the grid. The peaks can be colored with one of the primary

6   colors, the middle letters with a second primary color, and the troughs with the third primary color. The

7   background for the color can be either white or black. For initial training, the black background provides

8   a more pronounced image because the individual cone sensors will only be receiving information from

9   one depth plane.

10   When the subject views this color-depth grid of letters, their pre-attentive vision will counter any

11   switching of the letter ordering derived by the foveal vision. By switching back and forth between

12   attentive and pre-attentive vision the patient can train their foveal vision process to derive the correct

13   letter ordering for the color-depth letter grid.

14   As the subject's training progresses, the color or depth aspect to the grid can be eliminated and

15   white can be used instead of black for the background. In addition, different color-depth patterns can

16   be used. The peak to trough sequence could be reversed or the diagonal shift could be from right to left

17   going down the grid. The depth pattern could be changed to be a wave instead of a saw-tooth pattern,

18   etc. In any case, the order of the letters must be random and different for each color-depth letter grid

19   when the grid pattern is read from left to right and then right to left.

20   Patterns can also be produced that have actual words whose reverse spelling is a different word.

21   In this case the grid pattern should be read only from left to right. The presentation mechanism for the

22   display of the stereo images is not as restrictive as for the pre-attentive vision since the shape content is

1   very distinct and not degraded by texture composition or noise. Hence, even a slide viewer type display

2   could be used for administering the training.

3   The benefits and procedures associated with the use of the present invention in treating dyslexia

4   will now be demonstrated with reference to the following example:

5   **<u>EXAMPLE</u>**

6   **Background:**

7   In accordance with Disclosure Document Number 518,460, Watkins, Jessica Rae Watkins

8   ("Watkins") developed and administered a stereoscopic color-coded and depth-perception-based testing

9   and training program to three patients from Dr. Radenovich's Children's Vision Center in December of

10   2002, using equilateral triangles with four different orientations. The results of this experiment were that

11   of the three subjects thought to have dyslexic-like behavior, one did not show any difficulty in orientation

12   determination throughout the entire program of testing and training; but, the other two exhibited severe

13   problems with orientation determination during the baseline test and struggled throughout the training

14   program. These two subjects, however, did not exhibit any orientation determination difficulty during

15   the final testing. Discussions between Dr. Anthony Fierro of the Region 19 reading program and

16   Watkins indicated that the next step in validating the procedure used to treat dyslexia was to perform a

17   control group experiment.

18   **Objective:**
19
20   To perform an experiment using students diagnosed as having dyslexia and not having dyslexia.

21   These students were all given a traditional baseline test to determine their level of difficulty in performing

22   a visual orientation determination task. They were divided into two groups based on their scores and

23   were fist given either the stereoscopic training or placebo training. They were all given a second

24   orientation determination test to determine any change caused by the training given. They were then

1   given the training they did not receive first and were again tested for orientation determination to

2   determine any change following the second training.

3   **Rationale:**
4
5   What is currently thought to be the defining criteria for a person with dyslexia is their inability

6   to associate a particular letter symbol with a particular sound or phoneme. Researchers in the area of

7   treating dyslexia do not believe that dyslexia is caused by a vision problem since there are dyslexics who

8   have 20-20 vision. This test will demonstrate disagreement with the foregoing and further that dyslexia

9   could in fact be the result of the human foveal vision being un-calibrated in terms of orientation

10   determination. It is believed that when a person with dyslexia uses their foveal vision to identify letter

11   or number symbols they do not see the same symbol orientated in the same direction each time they try

12   to identify it.

13   This cause for dyslexia can be used to explain all of the symptoms of dyslexia, which includes the

14   inability of a person to associate a particular letter symbol with a particular sound or phoneme. The

15   biomimicking algorithm described in Disclosure Document 518,460 explains how predators with two

16   forward looking eyes (this includes humans) perform visual search, target acquisition, recognition, and

17   identification processes. One of the applications is the method that was used in this study as a potential

18   cure for dyslexia. In essence, humans use two distinct forms of vision. The first is a whole scene view

19   of the world around us. This is accomplished using what is called pre-attentive vision. Our pre-attentive

20   vision occurs automatically without having to think about it. This vision process is used to locate food

21   and danger. It is also used for navigating. The visual process elements that are used in this locating

22   process are called cues. The primary visual cues used in pre-attentive vision are motion, depth and color.

23   These cues allow us to locate possible food and danger and allow us to reposition the central portion of

24   our eyes (the fovea) on the object to be identified. The foveal vision is then used to identify the object

1 located by the pre-attentive vision using a process called attentive vision. Problems with reading can

2 occur because reading skips the pre-attentive vision phase and jumps straight to the attentive vision

3 process. Reading is not an automatic human function but rather is a learned skill.

4   The format for reading text is black letters on a flat white background. If an individual's foveal

5 vision is calibrated correctly for orientation determination, there is no problem learning to read if the

6 individual has normal vision. But, if the connections of the very small foveal region in our eyes' retinas

7 (a 0.5mm diameter circle with 60,000 color cone sensors) are not correctly channeled to the back portions

8 of our brains that perform the complex mental processing that produces the single picture we derive

9 from our two eyes, the images of letters that are seen many not have the proper orientation. In fact, the

10 letters may have random orientations each time they are viewed. The key to correcting the problem

11 would then be to calibrate the foveal vision in terms of orientation determination. That is exactly the

12 approach taken in this study. This is accomplished by using by using a symbol grid that contains depth

13 and color cues that can be used by both pre-attentive and attentive vision to allow the attentive vision

14 to be calibrated for orientation determination by transitioning the correctly determined orientation of

15 the pre-attentive vision to the attentive vision of the foveal region.

16   **Orientation Determination Test:**

17   Since it is symbol orientation determination and not letter identification that is important, only

18 triangles are used instead of any letters. The baseline test consists of five rows of ten triangles that have

19 one of four random orientations. The triangles point directly toward one of the four random directions

20 – up, down, left or right. A representation of this test is shown in Figure 2. This depiction is with black

21 triangles on a white background whereas the actual test that was displayed on two computer monitors

22 that were viewed with opposite eyes simultaneously had white triangles on a black background.

1   There were also two equivalent tests that were given after completion of each of the two training

2   programs – the foveal vision orientation calibration and the placebo.

3   The foveal vision orientation calibration training program consisted of five sessions given on

4   different days. They were stereoscopic displays where color and depth were added to the symbol grids

5   to allow the preattentive vision to lock the symbol grid in space and transfer this orientation information

6   to the foveal vision for calibrating its orientation. The task performed by the subject was slowly

7   transitioned from a primarily pre-attentive vision task to a solely attentive vision task of orientation

8   identification to accomplish the calibration of the foveal vision.

9   The placebo training program used the two-computer-viewing setup but did not contain any

10   depth or color cures for determining orientation. The test consisted of the letters "b", "d", "p", and the

11   vowels. The purpose was to see if simple three letter words with vowels as the second letter could be

12   properly identified and pronounced when they were hidden in a letter jumble line of ten of the same

13   letters per line. There were five words in each testing session and five letter jumble lines with one of the

14   words hidden in each line. The task that was given was to find at most one of the words in each line.

15   The subjects were timed in hopes of improving their concentration. The subjects were shown each of

16   the five words several times with different colored print by computer display just prior to testing. They

17   were given a printed sheet with the words to look at during the test.

18   One of these tests is shown in Table 1. The words "bad, bed, bid, bod, and bud" are hidden in

19   the five lines.

20   d a b p e b u d o b
21   o d e b i d a b u p
22   d i b u p o b e d a
23   b u p a b o d i b e
24   e b a d i p o d u b
25

26   Table 1. Placebo letter jumble test for bad, bed, bid bod, and bud.

1   Results:

2   The results of the orientation determination testing are shown in Table 2. The subjects are listed

3   as Group A or Group B. Group A received the calibration training first and then the placebo training.

4   Group B received the placebo training first and the calibration training.

5   Table 2. Orientation Determination Test Results
6

7
	A-1	A-2	A-3	B-1	B-2	B-3
Test 1	8/0	4/1	1/0	10/0	2/4	3/0
Test 2	0/0	0/0	0/0	12/0	0/2	25/0
Test 3	0/0	0/0	0/0	0/2	0/0	0/0

13   The entries for the subjects for each test consist of the number of incorrect orientation

14   determinations out of the fifty triangles followed by the number of determinations that were stated and

15   then changed. As can be seen after the orientation training had been given, none of the subjects made

16   any mistakes in orientation determination and only two reversals were made. In general, the subjects that

17   received the placebo training first (Group B) did about the same on the second test except for subject

18   B-3. This subject reversed every left and right orientation determination. The possible reason for this

19   will be discussed after discussing the placebo test results.

20   The placebo test results are combined for the four tests taken in Table 3. There were 20 total

21   words that could have been found, five from each test. The results are given as the number of correctly

22   found and pronounced words followed by the number of words not found followed by the number of

23   incorrect words pronounced by Group A that had received the orientation calibration training first.

24   There was only one incorrect answer and that was a repeat of the word from the previous line. The

25   subject may have looked at the word list and then looked at the wrong line and found the same word

26   twice. Also of interest is the subject B-3 that had no trouble finding any of the words until the last test.

1   This was the test shown in Table 1. The subject identified the last three letters of the sequence "dub"

2   as "bud" and pronounced it as "bud". It is very interesting that this individual also reversed every left

3   and right orientation identification in test 2 two days later. It is possible that this phenomenon could

4   have been caused by allergies. It is not known if the orientation calibration has corrected this problem

5   for the condition when the individual has allergy symptoms. Subject B-3 did not make any orientation

6   determination mistakes in the final test.

7   Table 3. Placebo Letter Jumble Test Results

8

9

	A-1	A-2	A-3	B-1	B-2	B-3
4 Tests	15/5/0	19/0/1	19/1/0	8/0/12	18/1/1	19/0/1

10

11

12

13   In terms of improved letter identification and word pronunciation, subjects A-1 and B-1 will be

14   compared. Both had difficulty with the first orientation determination test. Subject B-1 correctly found

15   and pronounced only 8 out of 20 words in the placebo testing before having received the orientation

16   calibration training. Of special note is the score for the test shown in Table 1. Only one of the words

17   was correctly found and pronounced and four incorrect words were given. Upon completion of the final

18   test, subject B-1 was given the last placebo session again. This time three words were correctly found.

19   The first mistake was the word "bed" was given for "bid." The subject was asked to locate the word

20   found in the letter jumble line and identified the letters "bid." The subject was asked to pronounce the

21   word found and again said the word "bed." It appears that the ability to correctly identify letters has

22   been accomplished, but the association of the correct phoneme with the identified letter still requires

23   further training. The processed foveal vision is sent to the left side of the brain, and subjects with

24   orientation determination difficulties will have to learn how to associate the correctly identified letters

25   with the proper phonemes for use in the left side of the brain. To see how different the two vision

1   processes are is possible by taking another look at the problem experienced by subject B-3. Before each

2   test the subjects are shown in a large black card with a white triangle on it. They are shown the card

3   orientation that represents the pointing of the triangle for up, down, left and right. After subject B-3

4   reversed every left and right triangle orientation determination on test 2 that have symbols so small that

5   they can only be identified using attentive vision, the subject was asked to identify the orientation of the

6   large triangle. The subject properly identified left and right that could be accomplished using pre-

7   attentive vision because of the size of the triangle.

8   The subject could now use the sense of touch to reinforce their visual orientation skills. A set

9   of cards with small letters (on the order of 0.6 cm in height for viewing from a distance of 40 cm) printed

10   on each card and a black border to represent the bottoms are used. The subjects could be given single

11   letters, multiple letters or words. A set of transparent disks with the same size letters printed on them

12   is used. The subjects must choose the disks with the proper letters and orient them to exactly overlay

13   the card letters. For each letter, the letter is identified and its sound spoken. If a word is used, the word

14   is spoken after all its letters have been oriented and identified. The sense of touch is thus used to

15   reinforce the visual orientation and letter identification task skill.

16   **Other testing:**

17   There were two other vision tests that were give by Allen and Virginia Crane in conjunction with

18   the orientation determination testing. The subjects were given an eye tracking test that included the

19   reading of simple story and a set of ten questions associated with the content of the story while the

20   subject's eye tracking was measured. They were then given a test of symbol identification speed (PAVE).

21   There was a significant amount of data collected on the actual eye tracking during each reading but would

22   take a significant amount of explanation to be fully understood. Instead only the reading comprehension

23   and symbol identification speeds will be shown in Table 4.

1   Table 4. Eye Tracking and Reading Comprehension Testing
2

	A-1	A-2	A-3	B-1	B-2	B-3
Story 1	5/10	6/10	9/10	8/10	9/10	10/10
Story 2	7/10	8/10	10/10	9/10	10/10	10/10
Story 3	8/10	10/10	9/10	10/10	10/10	10/10
PAVE 1	30	60	60	35	30	50
PAVE 2	20	30	55	20	30	25
PAVE 3	35	50	85	35	45	50

13   What is of note from Table 4 is the reading comprehension improvement for subjects A-1, A-2

14   and B-1. All of the subjects improved or maintained their comprehension level. Subject A-3 missed one

15   question in each Story 1 and Story 3 but was reading at well above their grade level. There was a little

16   problem with the PAVE results because the test was given differently the second and third times, which

17   may have biased the first results that appear high. Even so, the speed at which all the subjects were able

18   to identify a particular symbol increased dramatically between PAVE 2 and PAVE 3. The number refers

19   to how many lines of three symbols were shown per minute and correctly counted. The three symbols

20   were blinked onto the screen sequentially one after the other while the line was viable.

21   **Conclusions:**
22
23   The results of this study were very positive. All of the subjects have improved their symbol

24   identification capabilities with their now calibrated foveal vision. They now have the tools to correctly

25   identify symbols such as letters and begin to associate the appropriate phonemes with these symbols

26   using the left portion of their brains. Many of the subjects were not able to do this before the testing and

27   training program. All of the subjects demonstrated improved concentration and eye coordination in

28   reading with improved reading comprehension. For those subjects that are seeing the letter symbols with